EUROnu Super Beam Work package

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For the WP2 team

EURONu Review
CERN
April 14 2011

Outline

- The project and the challenges
- Target – horn design status
- Physics reach and optimization
- Ongoing activities

The WP2 team

- Cracow University of Technology
- STFC RAL
- IPHC Strasbourg
- Irfu-SPP, CEA Saclay

- O. Besida, C. Bobeth , O. Caretta , P. Cupial , T. Davenne , C. Densham, M. Dracos ,M. Fitton , G. Gaudiot, M.Kozien ,B. Lepers, A. Longhin, P. Loveridge, F. Osswald , M. Rooney ,B. Skoczen , A. Wroblewski, G. Vasseur, N. Vassilopoulos, V. Zeter, M. Zito

Activities

- Beam simulation and optimization, physics sensitivities (Saclay)
- Beam/target interface (RAL)
- Target design (RAL, Strasbourg)
- Horn design (Strasbourg, Cracow)
- Target horn integration (Strasbourg, Cracow)
- Target station (RAL)
- Regular phone meetings + two face to face meetings per year

Motivation

- Conventional neutrino beams are a powerful tool for the study of neutrino oscillations
- Currently several large scale HEP experiments using this technology: MINOS, OPERA, T2K
- Can we conceive a neutrino beam based on a multi-MW proton beam ?
- At the start of EUROnu, no proven solution for the target and collector for this facility !

Super-Beam

Far detector

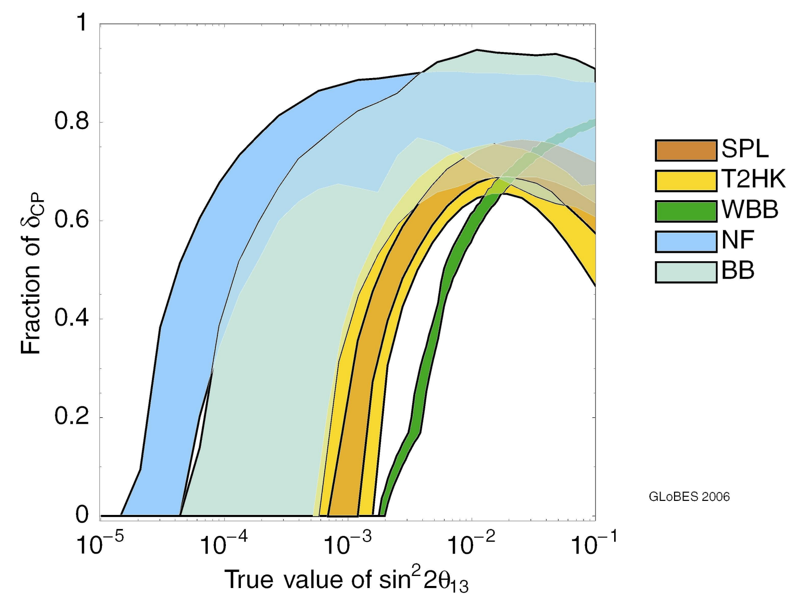
Target+Collector

Multi
Proto
Drive

P

- **Can we design a target for a multi-MW proton beam ?**

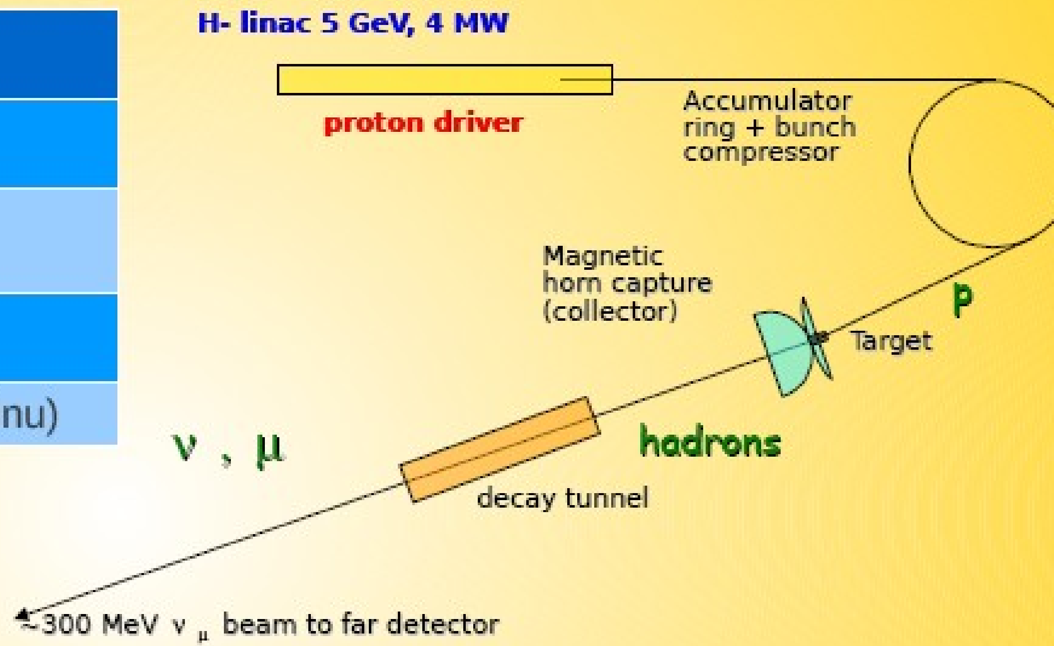
- **Can we do it with a reliable design without compromising the physics reach ?**

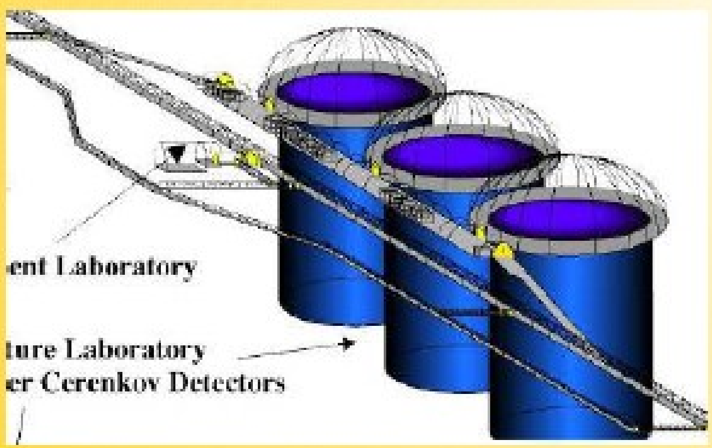


CERN to Fréjus

Basic scenario (detector, proton energy) is well defined

Beam Energy	5 GeV
Baseline	130 km
Far detector	MEMPHYS
Mass	440 kton
Running mode	2 y (nu) + 8y (antinu)





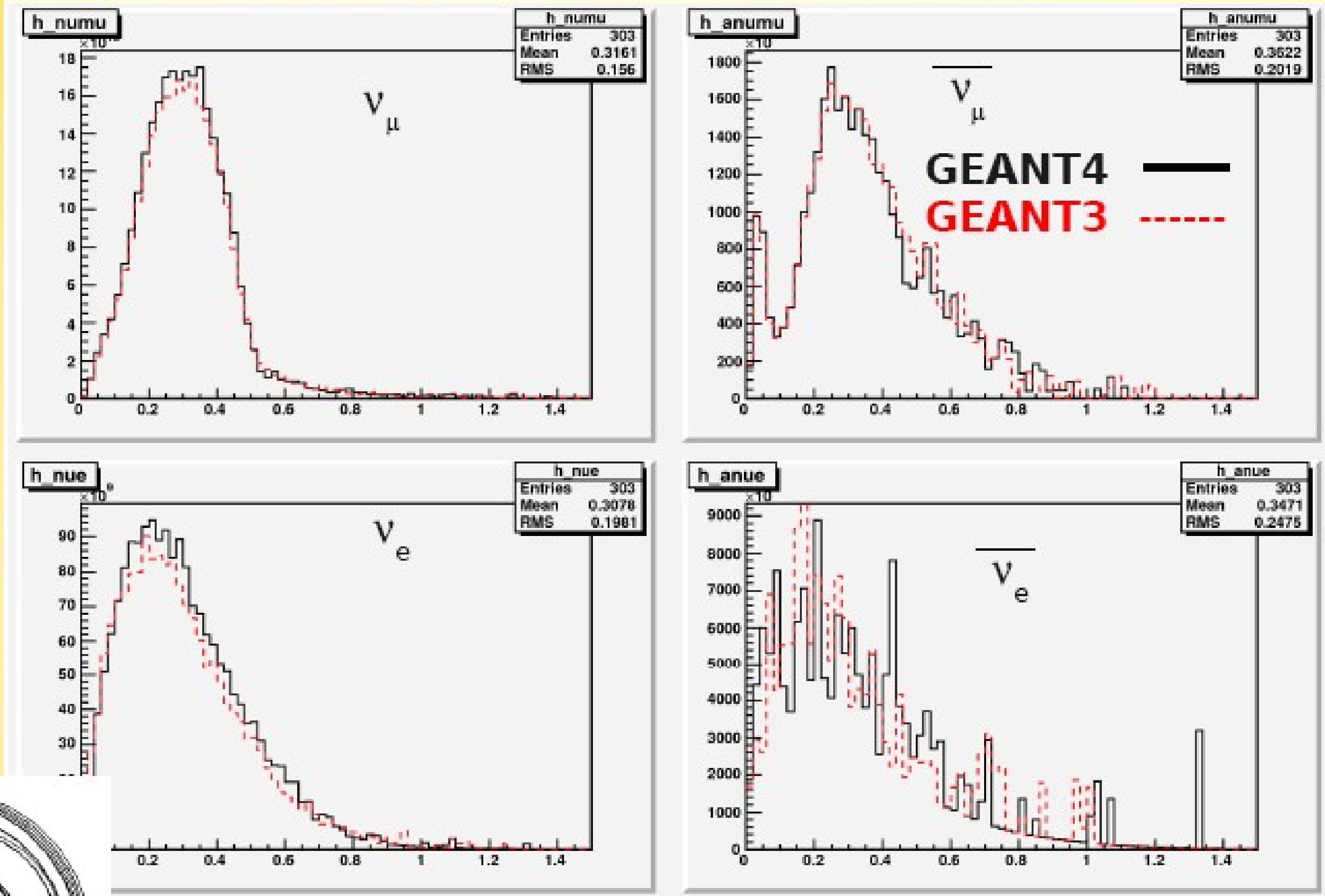
Proton beam

Energy	4.5 GeV
Beam Power	4 MW
N. beam lines	4
Rep. rate	12.5 Hz
Pulse dur.	5 μs
beam gauss width	4 mm

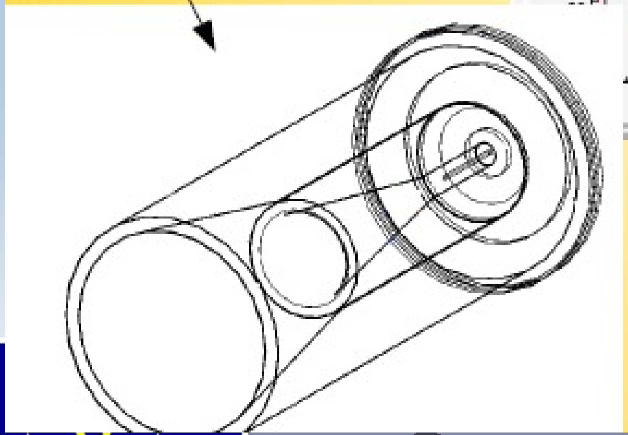
GEANT3-4 comparison with SPL standard horn

The original GEANT3 software (A. Cazes) rewritten in GEANT4

Fluxes comparison with the original horn geometry



standard horn geometry (GEANT4)

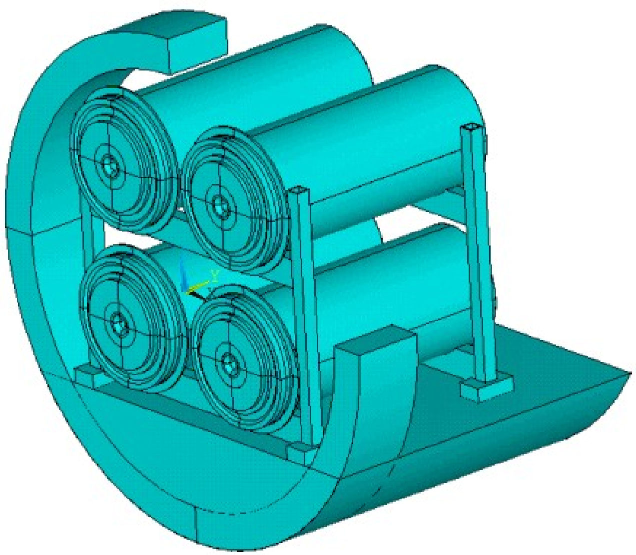


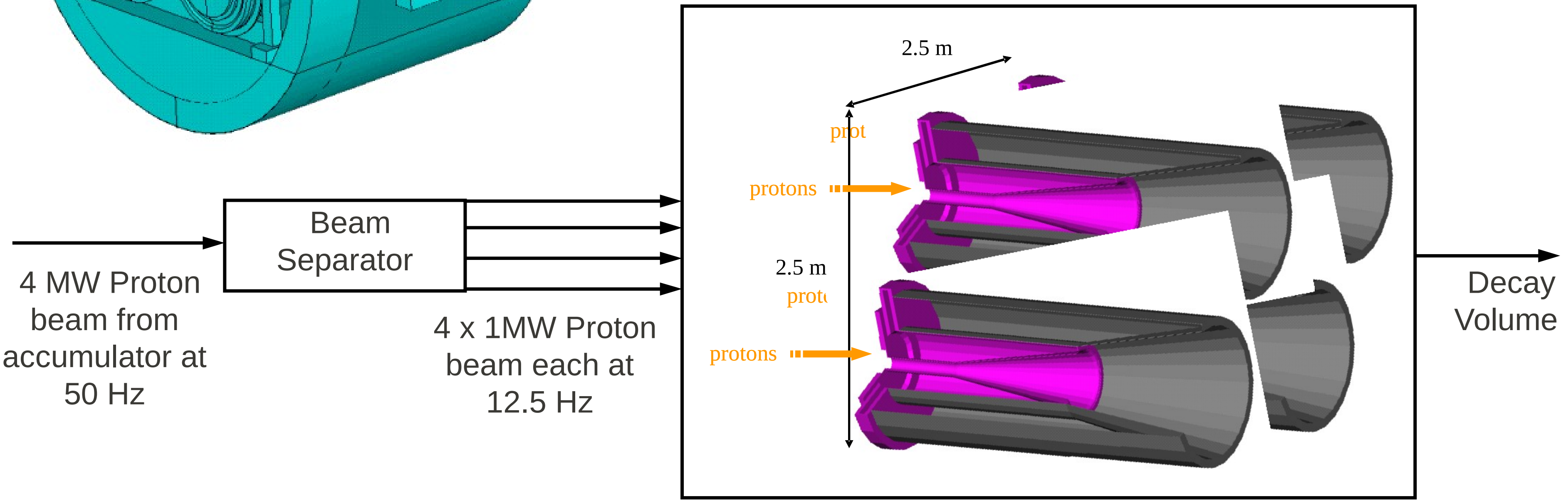
Good agreement found between the two simulation programs

Important steps for the design

- Solid static target
- Use multiple (4) targets+collectors
- Each pulsed at 12.5 Hz
- Use single horn (no reflector)
- Optimization of horn shape → Miniboone shape
- A lot of progress towards a working solution, at constant (or improved) physics performance

Overall configuration

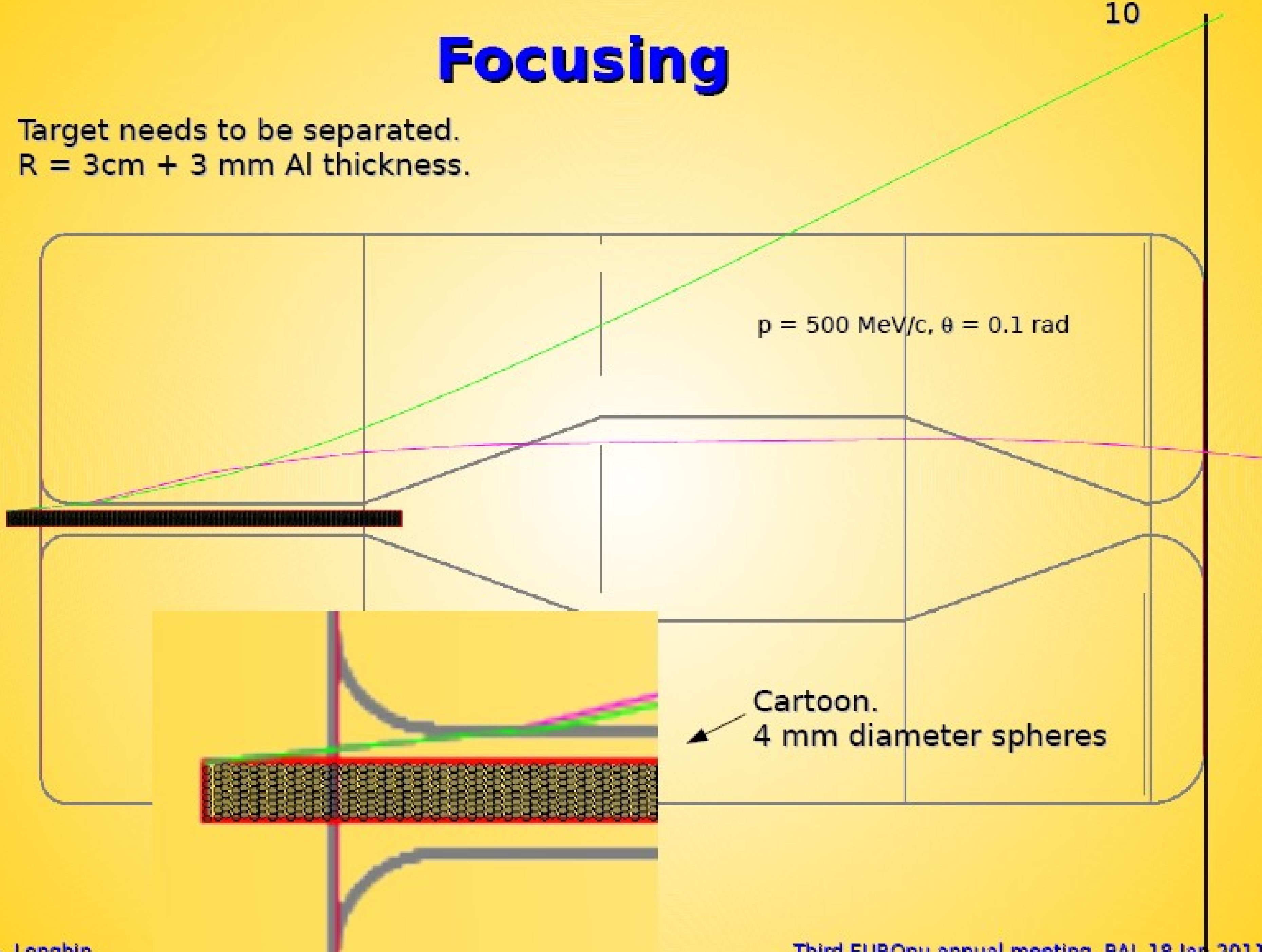




Target Station (4 targets, 4 horns)

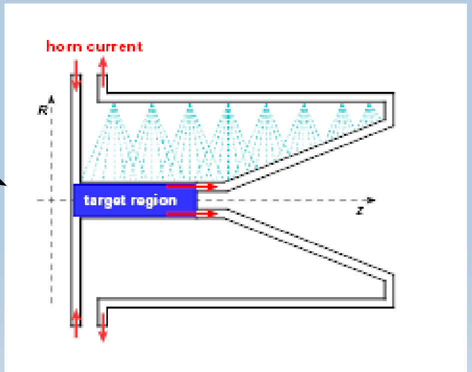
Focusing

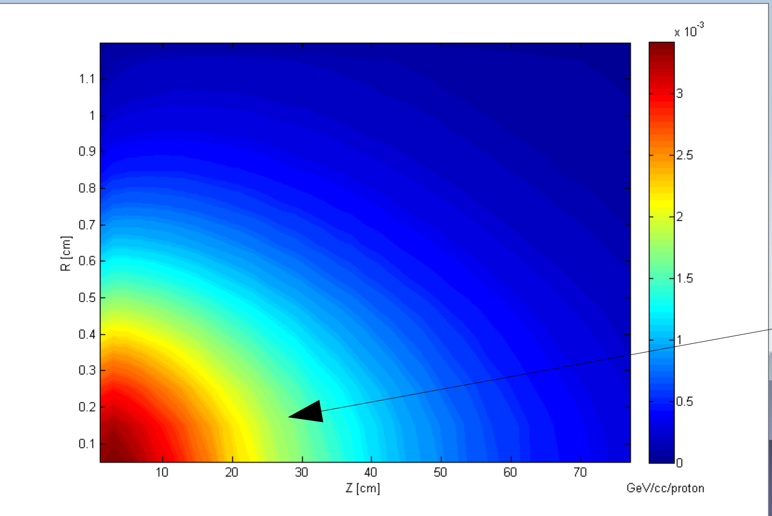
Target needs to be separated.
R = 3cm + 3 mm Al thickness.



Target studies and baseline

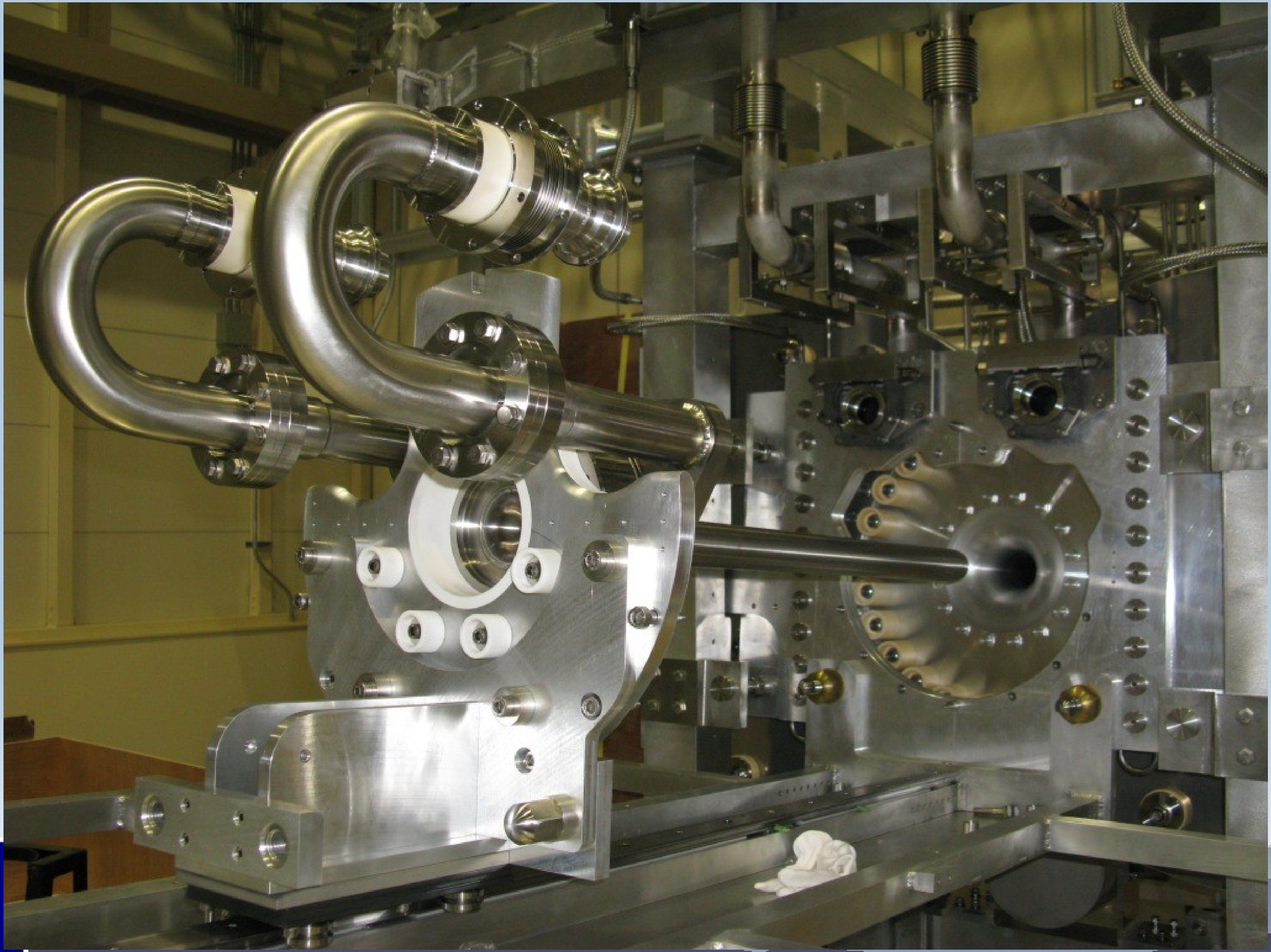
- In the past months we have focused on the target design
- We have considered:
    - A solid static low-Z target cleverly shaped
    - A one-piece (embedded) target+horn (conducting target)
    - A pebble bed target





A critical issue: very high power density in the upstream central volume

T2K graphite target



C. Densham, T. Davenne

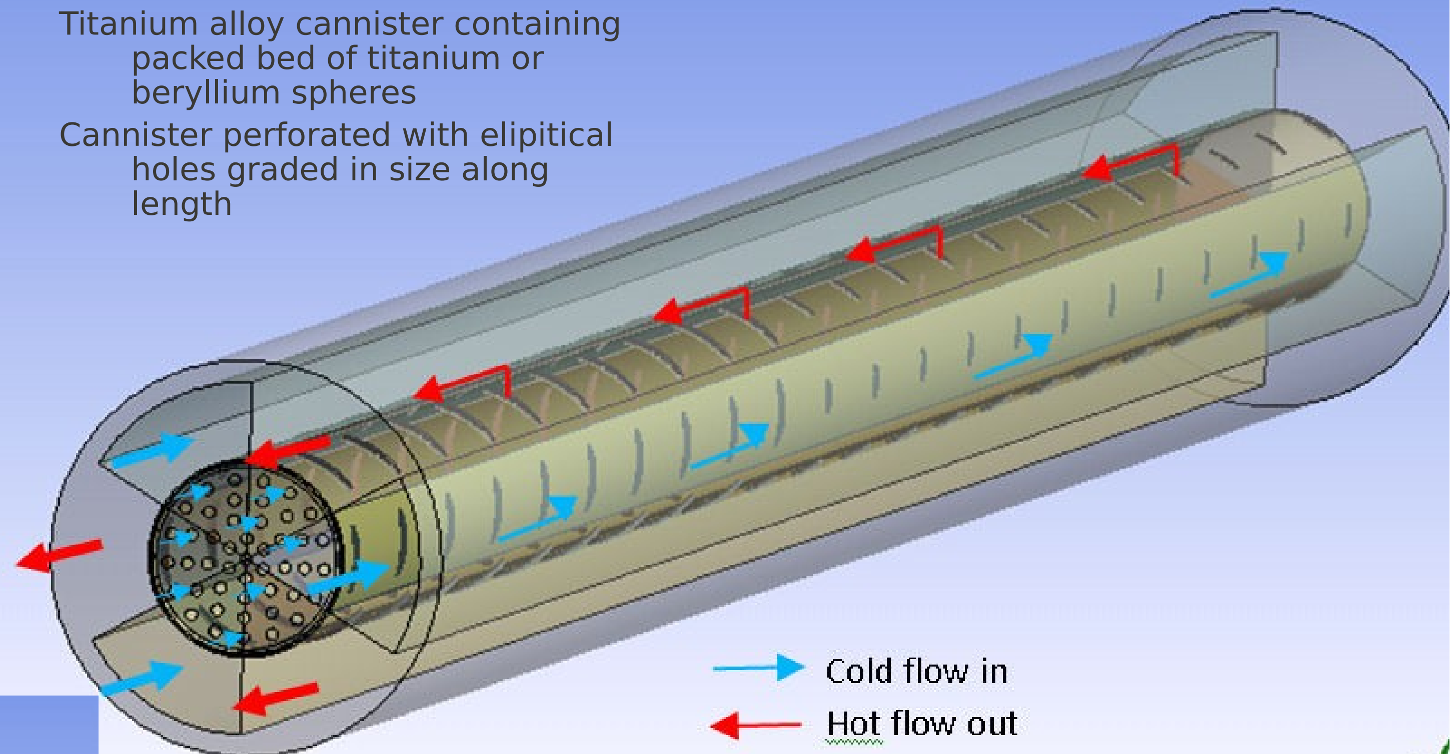
Packed Bed Target Concept for Euronu (or other high power beams)

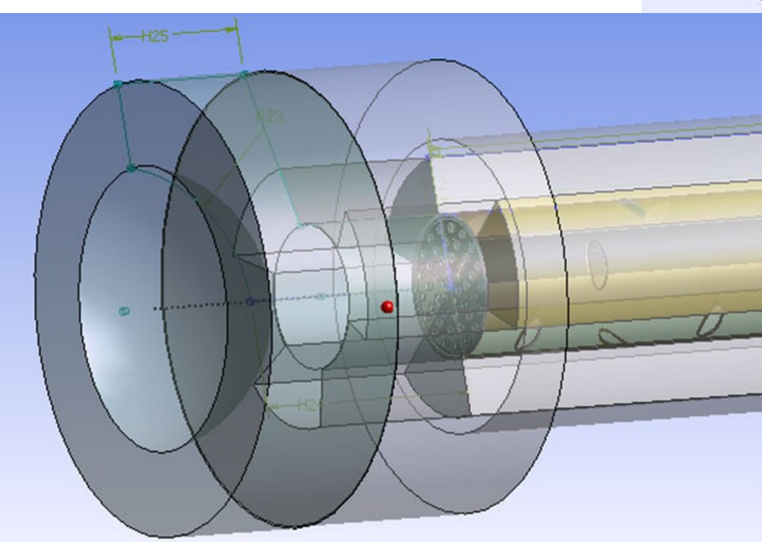
Packed bed cannister in parallel flow configuration

Packed bed target front end

Titanium alloy cannister containing packed bed of titanium or beryllium spheres

Cannister perforated with elipitical holes graded in size along length





Model Parameters

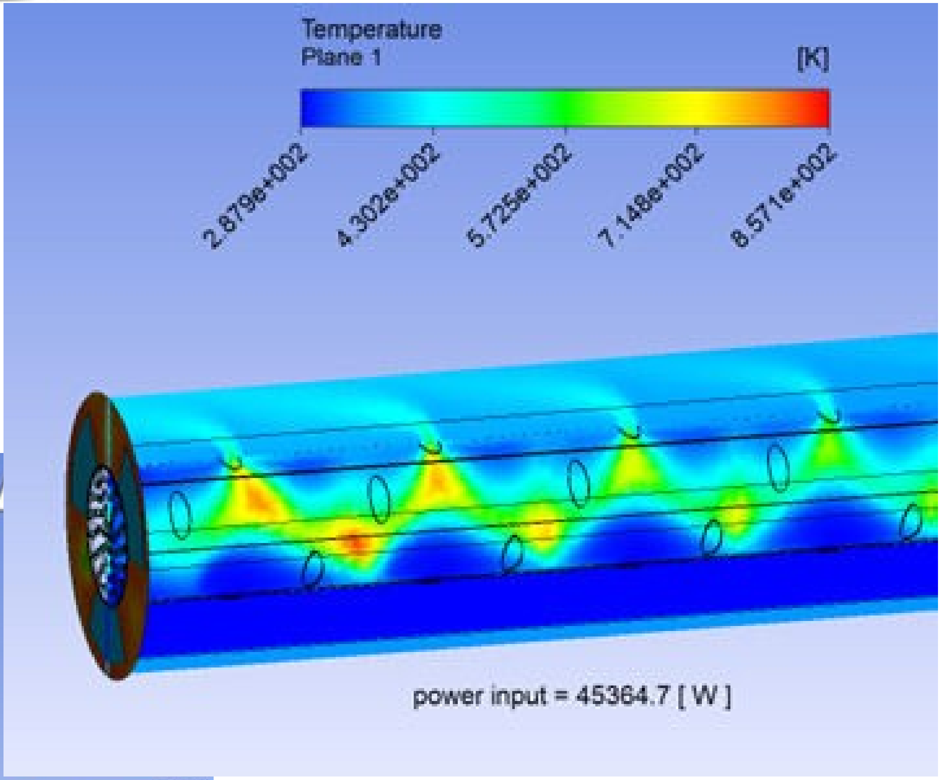
Proton Beam Energy = 4.5GeV
Beam sigma = 4mm
Packed Bed radius = 12mm
Packed Bed Length = 780mm
Packed Bed sphere diameter = 3mm
Packed Bed sphere material : Beryllium or <u>Titanium</u>
Coolant = Helium at 10 bar pressure

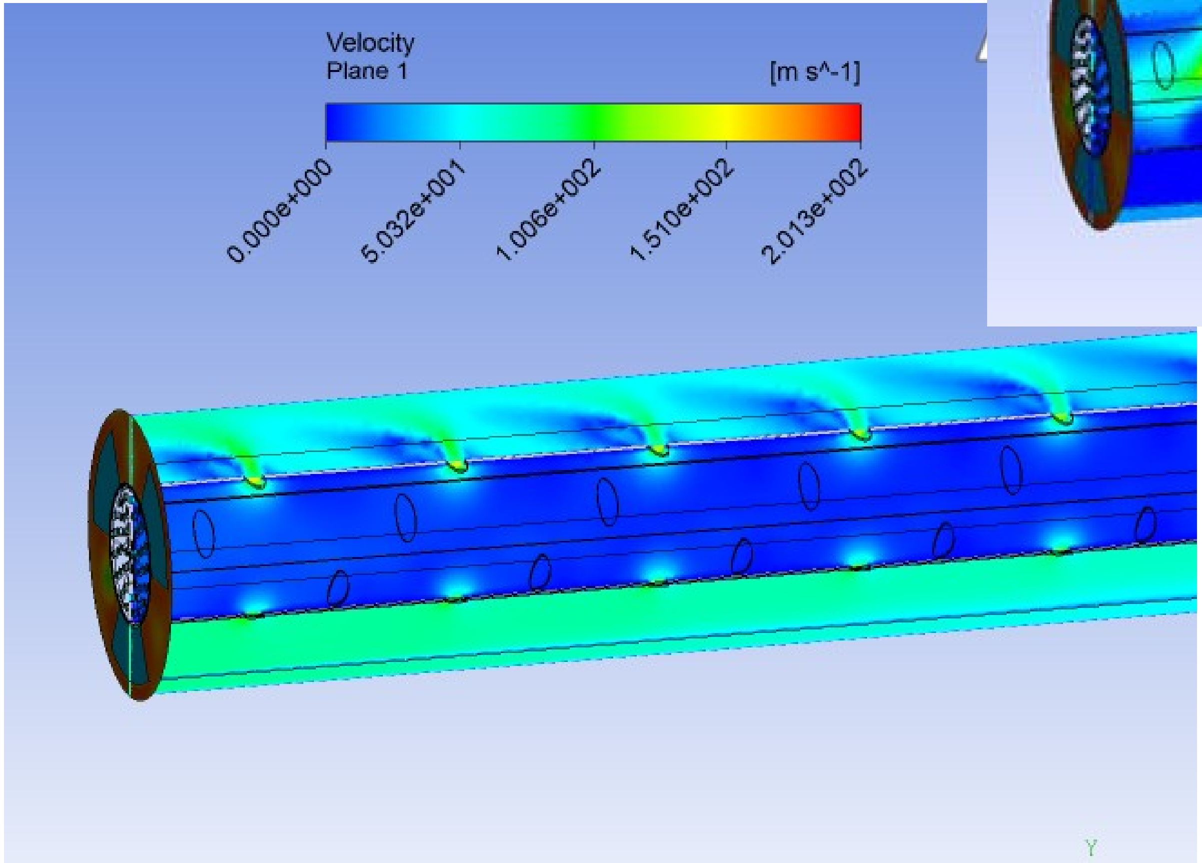
Helium Flow

<u>Helium Velocity</u>

Maximum flow velocity = 202m/s

Maximum Mach Number < 0.2





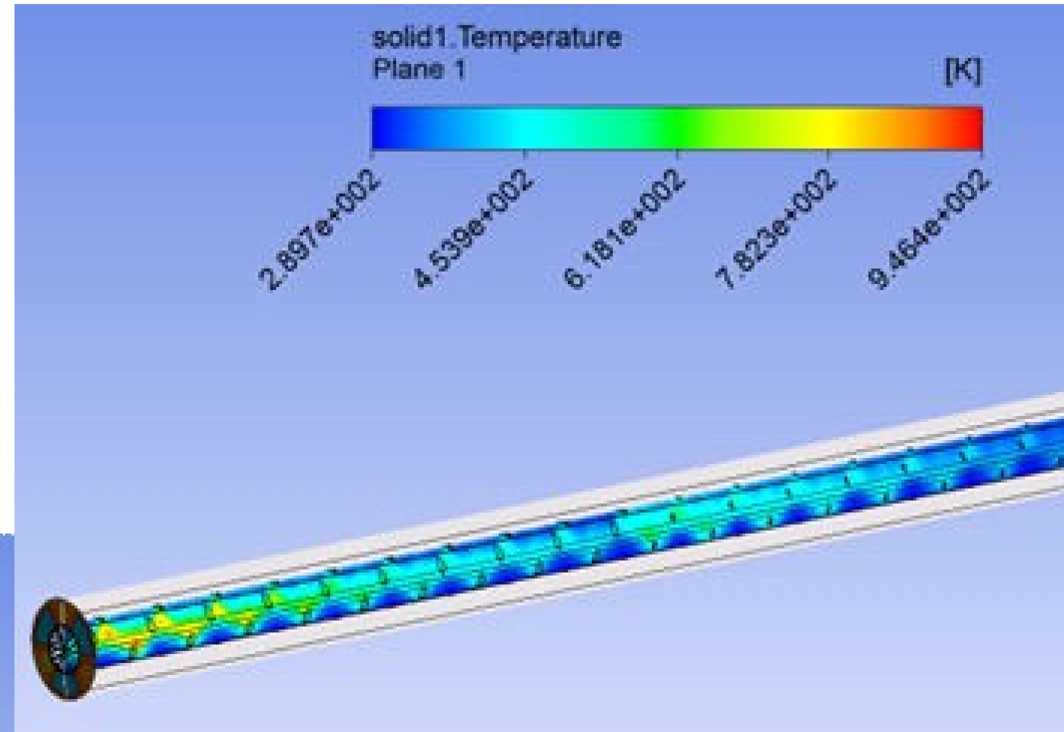
<u>Helium Gas Temperature</u>

Total helium mass flow = 93 grams/s

Maximum Helium temperature = 857K =584°C

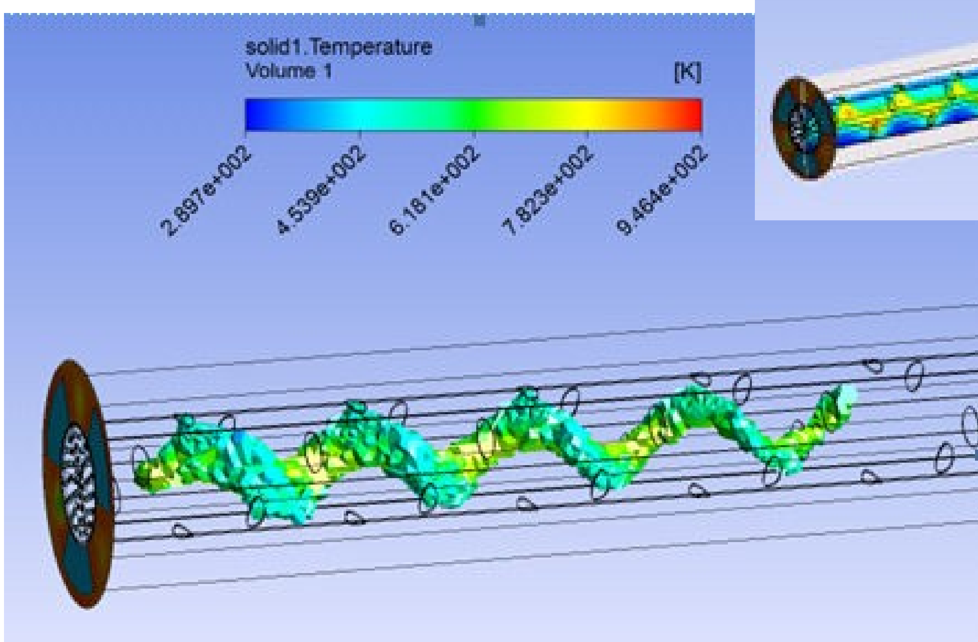
Helium average outlet Temperature = 109°C

Packed Bed



<u>High Temperature region</u>

Highest temperature Spheres occur near outlet holes due to the gas leaving the cannister being at its hottest



<u>Titanium temperature contours</u>

Maximum titanium temperature = 946K =673°C (N.B. Melting temp =1668°C)

Towards the target baseline

After these studies we have concluded that

- The pebble bed target appears to be the best candidate (capable of multi-MW) → baseline choice
- The solid static target is feasible, pencil shape solution
- The embedded target is disfavored

Horn

Baseline :

- Miniboone shape
- Aluminum
- Cooled with internal water sprays
- Pulsed with 300-350 kA

GEOMETRY

Parameters	value [mm]
L_1, L_2, L_3, L_4, L_5	589, 468, 603, 475, 10.8
t_1, t_2, t_3, t_4	3, 3, 3, 3
r_1, r_2	108
r_3	50.8
R^{tg}	12
L^{tg}	780
z^{tg}	68
R_2, R_3	191, 359
R_1 integrated	12
R_1 non integrated	12 + 28 = 40

TABLE: Horn geometric parameters.

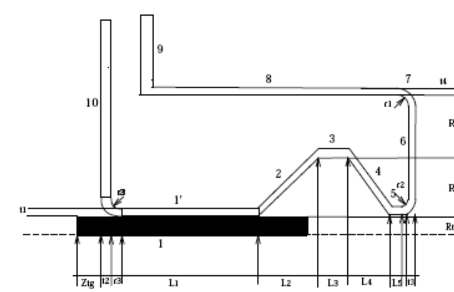


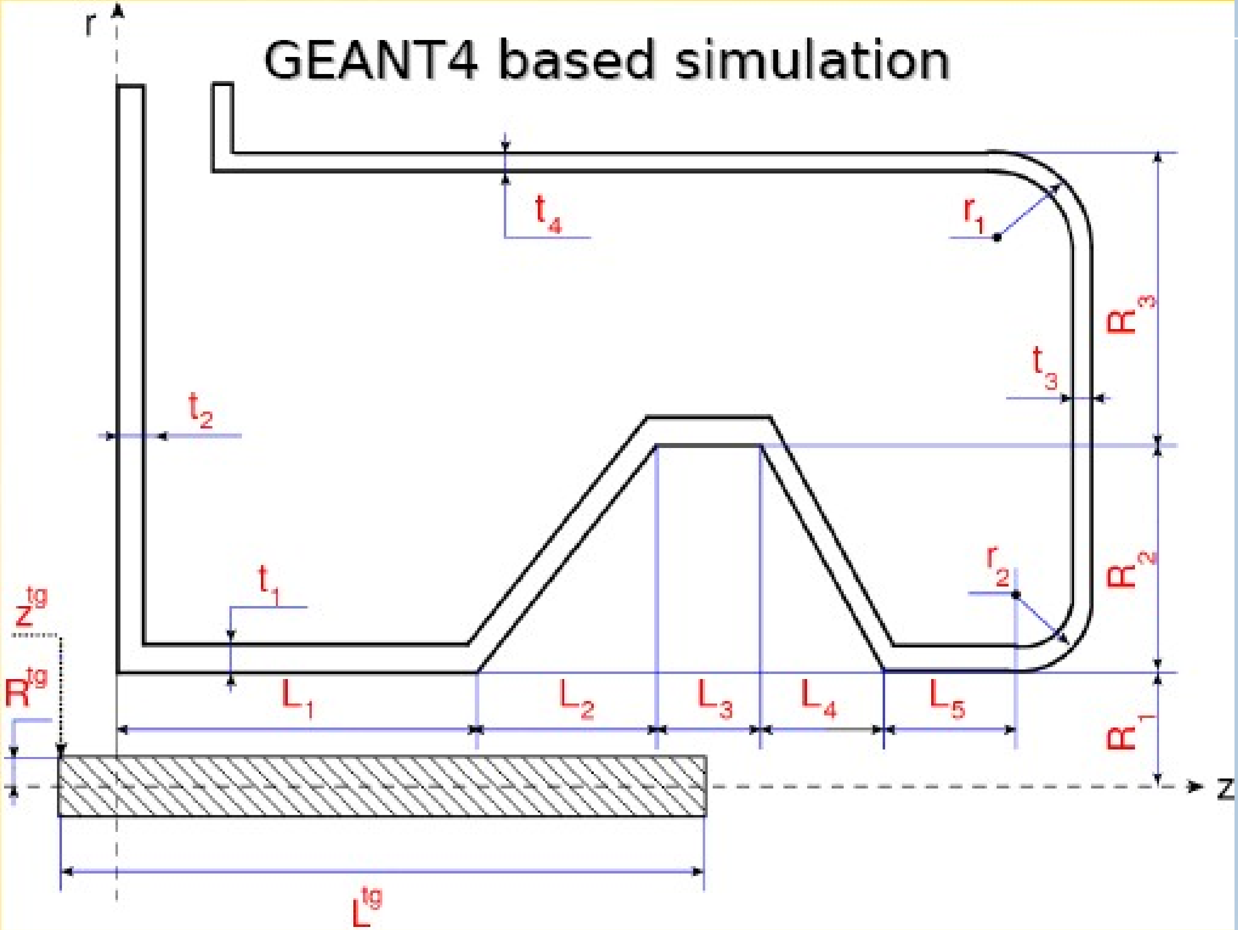
FIGURE: Horn parameters.

Horn geometrical model

à la MiniBoone
("forward closed")

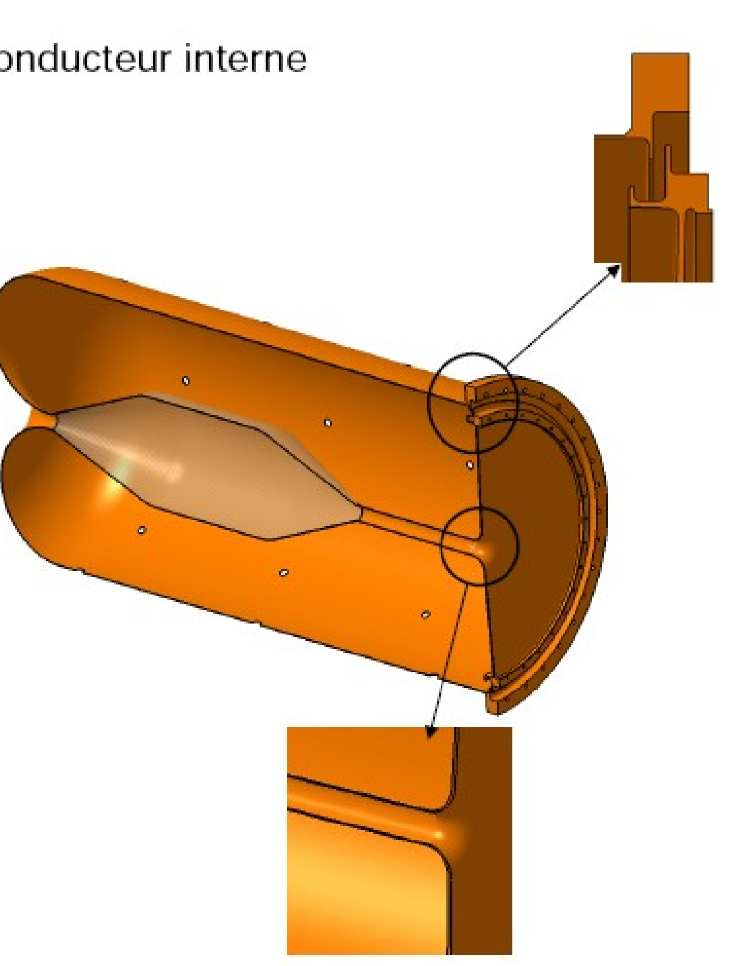
large acceptance for forward produced particles

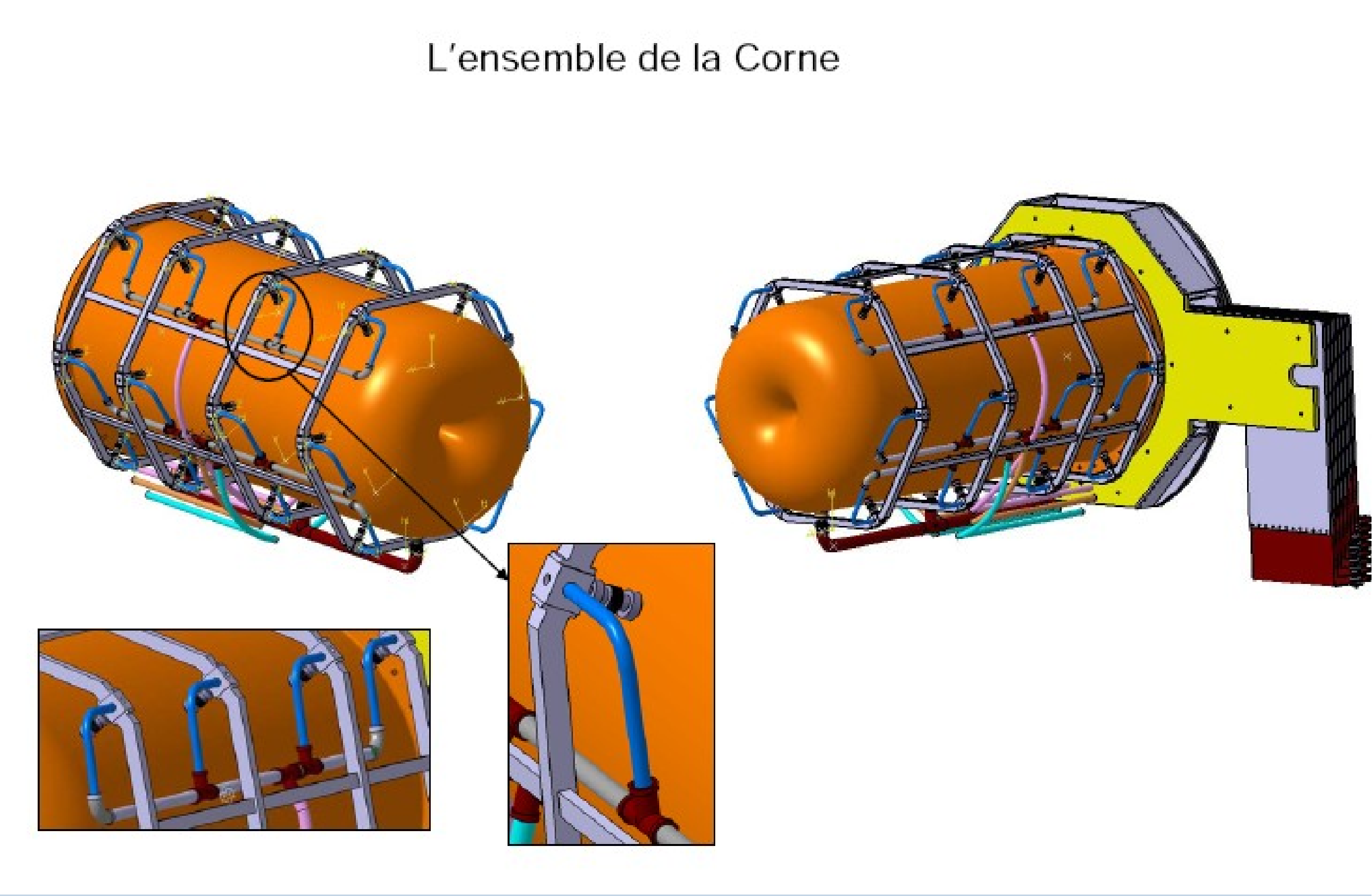
This shape is well suited for long targets



Good suppression of wrong charge pion dangerous in "-" focusing mode due to ν_e from $\pi^+ \rightarrow \mu^+ \rightarrow e^+ \nu_e \overline{\nu}_\mu$ and $K^+ \rightarrow \pi^0 e^+ \nu_e$ ← EUROnu-WP2 note 09-01

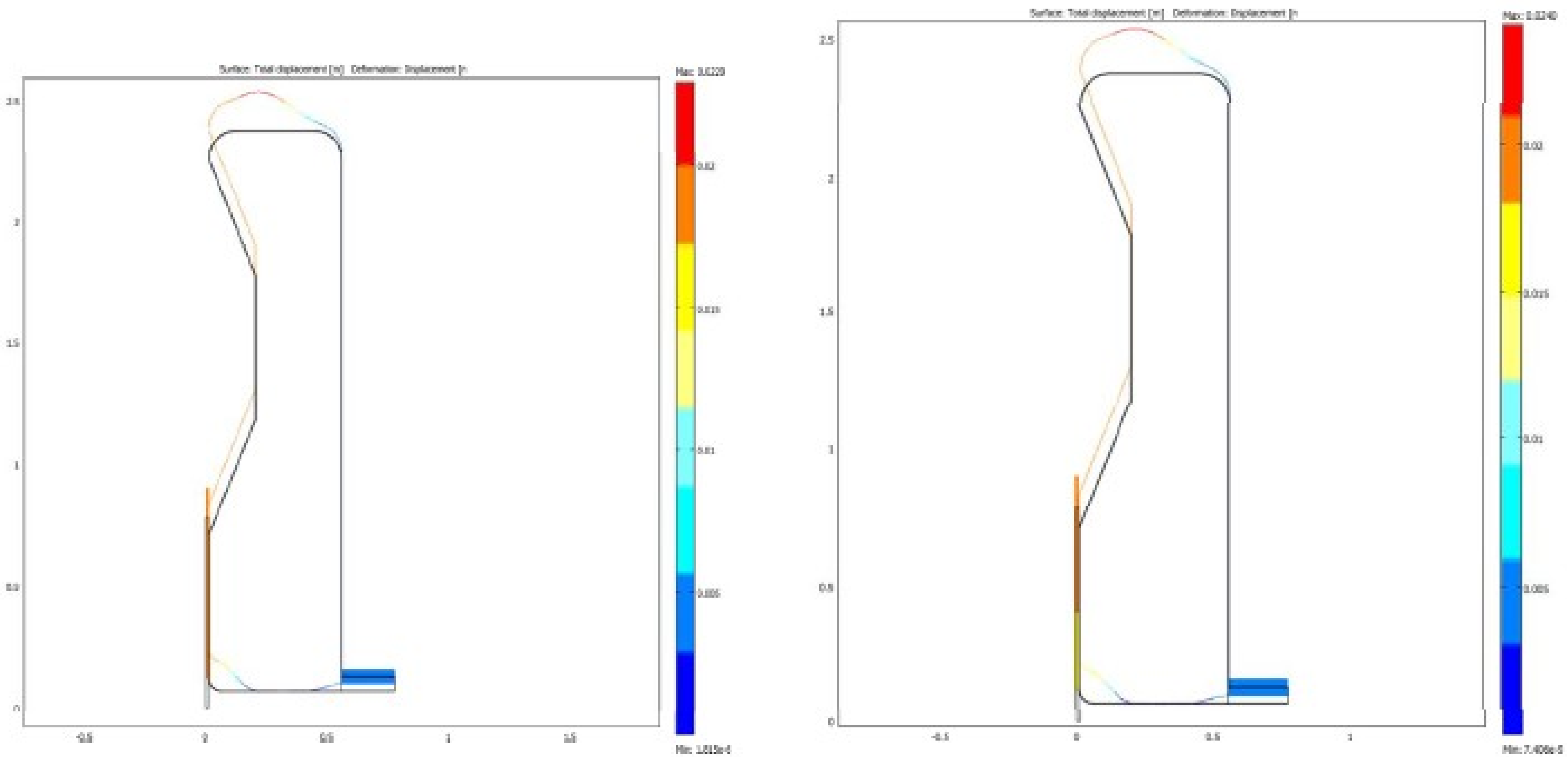
Horn drawings with cooling system





Displacement field, $t = 3$ mm

B. Lepers

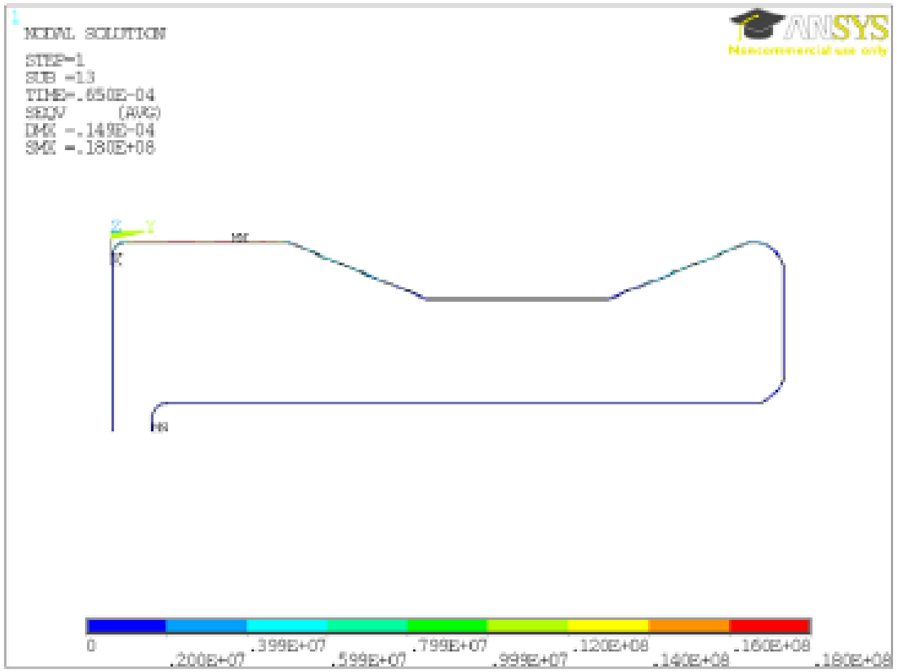


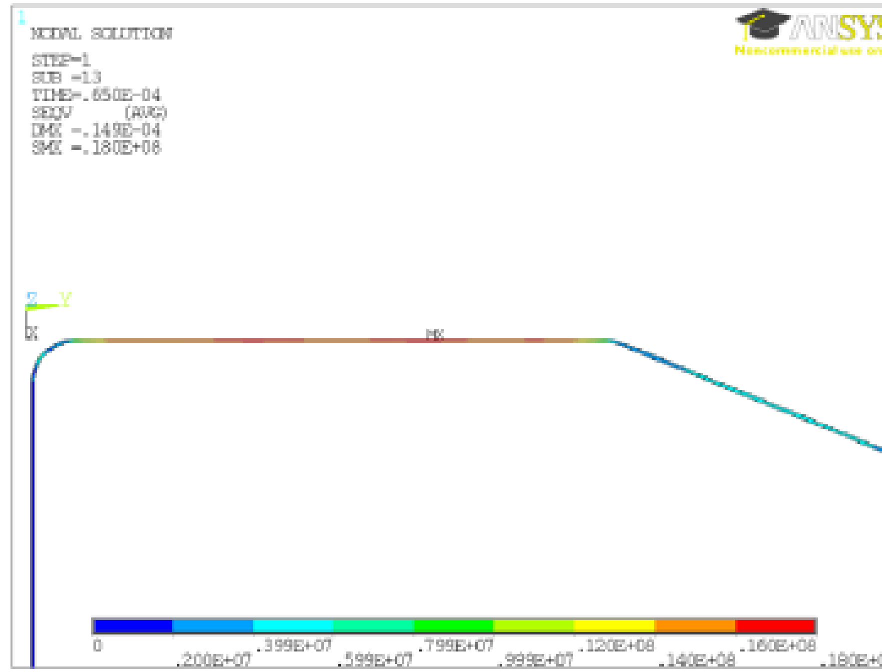
a) b)

FIGURE: Displacement field for the horn with thickness $t = 3$ mm, magnetic pressure $u_{max} = 23$ mm a) and magnetic pressure + thermal dilatation $u_{max} = 24$ mm b) for cooling scenario 2

Response to magnetic pulses

P. Cupial





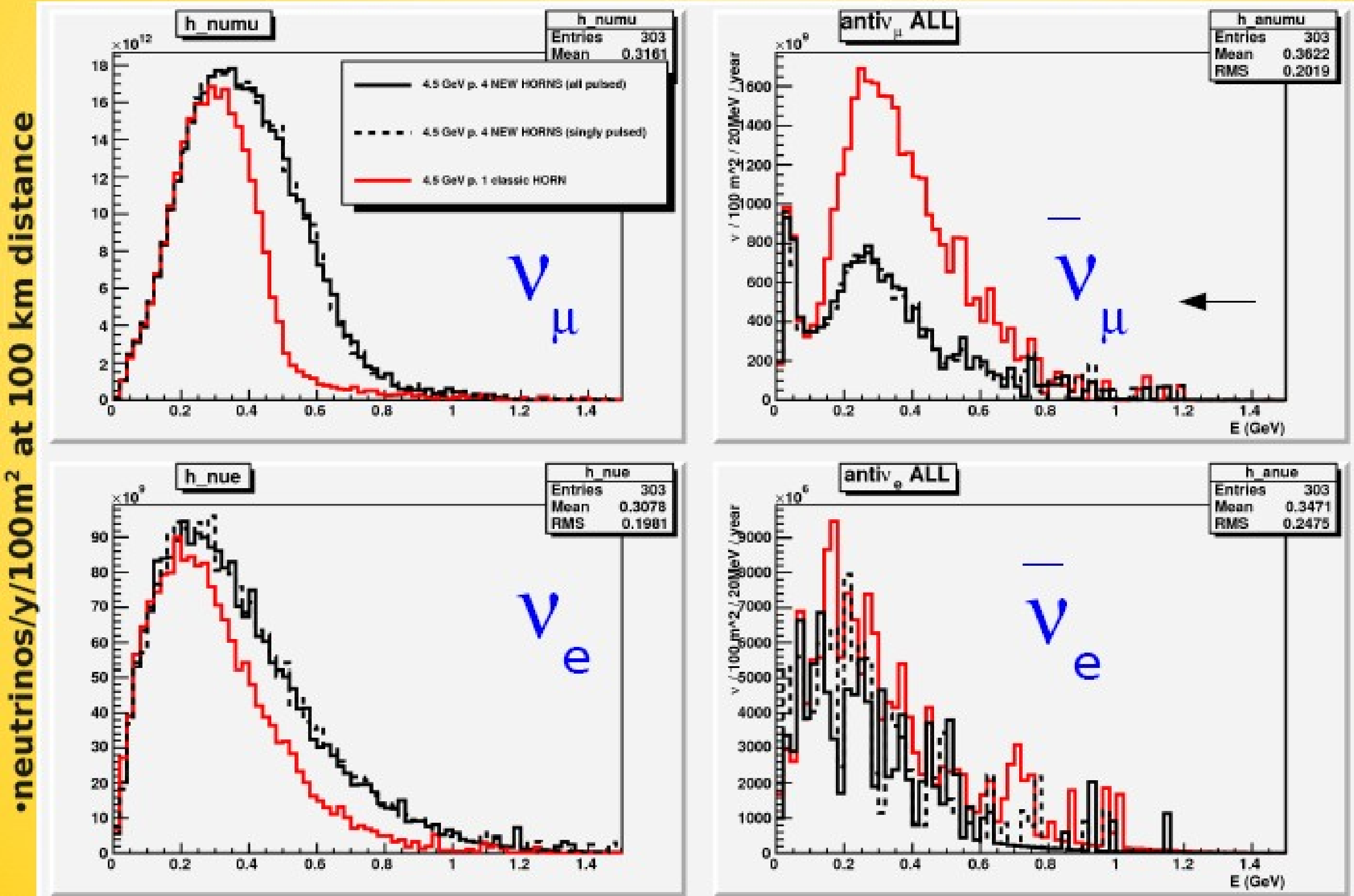
Maximum von Mises stress due to magnetic pulses = 18 MPa (at 300 kA)

= 24.5 MPa (at 350 kA)

Fluxes: new VS old horn

Carbon target
new horns / old horn

- gain ν_μ at higher energies
- Effectively suppressed contributions from wrong charge pions (more than a factor 2 less anti-ν_μ, lower anti-ν_e +c.c.)



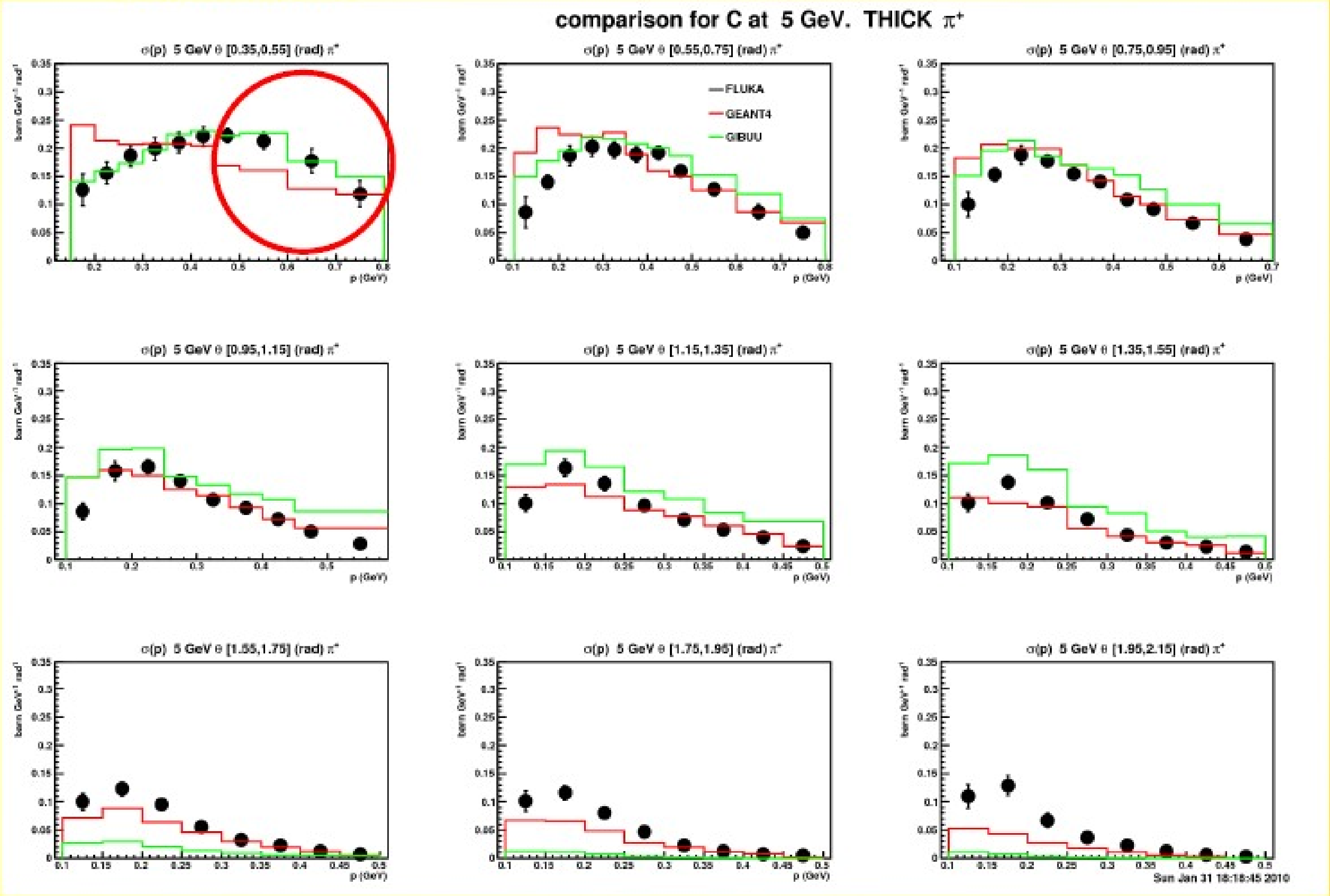
GEANT4

@ 4.5 GeV positive focusing

	OLD (%)	NEW (%)
+ FOCUSING		
ν_μ	88.9	-> 95.55
$a\nu_\mu$	10.5	-> 3.9
ν_e	0.6	-> 0.56
$a\nu_e$	0.052	-> 0.025
- FOCUSING		
ν_μ	26.1	-> 11.2
$a\nu_\mu$	73.4	-> 88.4
ν_e	0.17	-> 0.09
$a\nu_e$	0.34	-> 0.35

HARP-GEANT4-GIBUU. Large angle. THICK target. C. 5 GeV. pi+

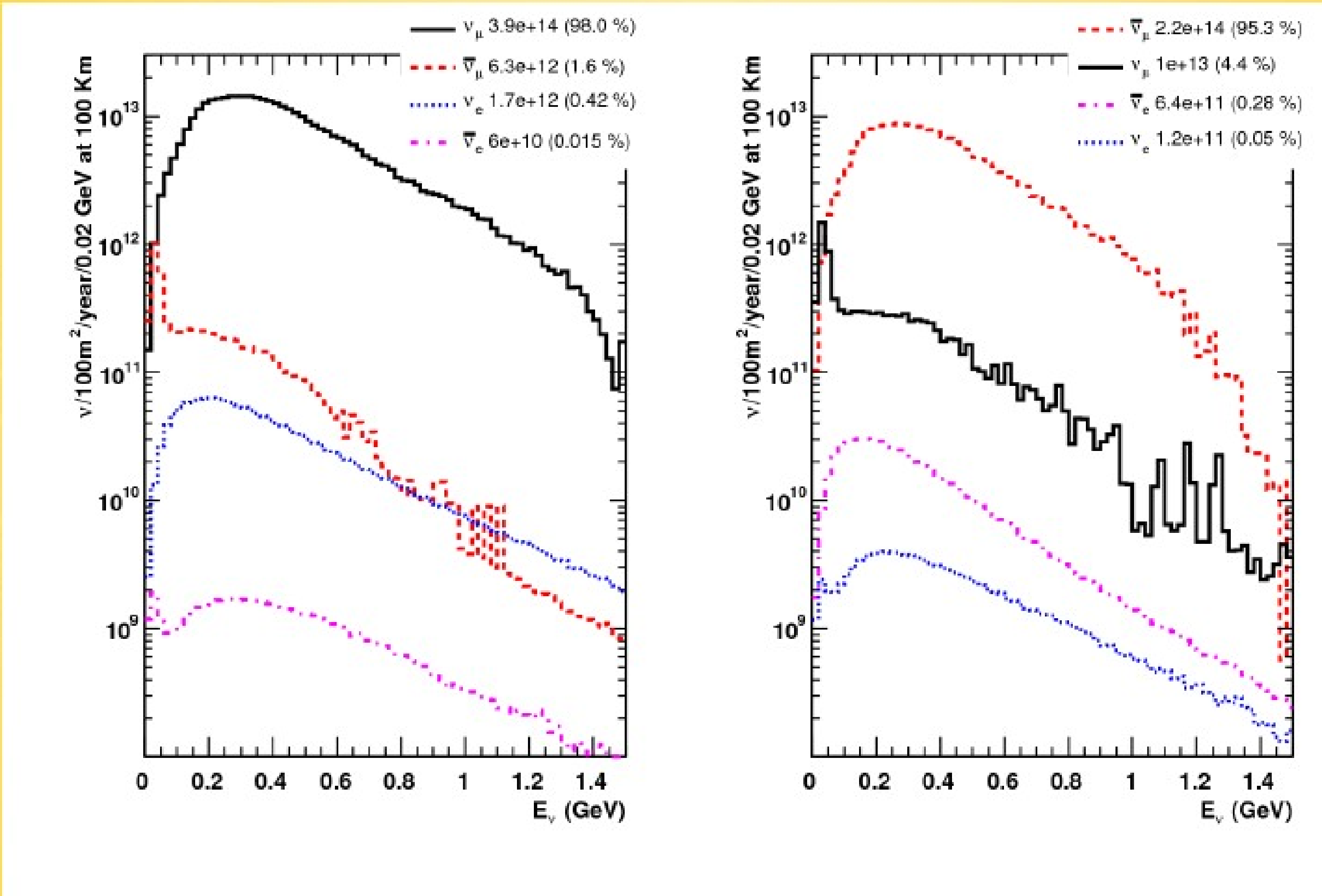
σ(p) in θ bins



tends to underestimate production at large angles

GIBUU rather good in the interesting region (high p, small θ)

Optimised horn: fluxes

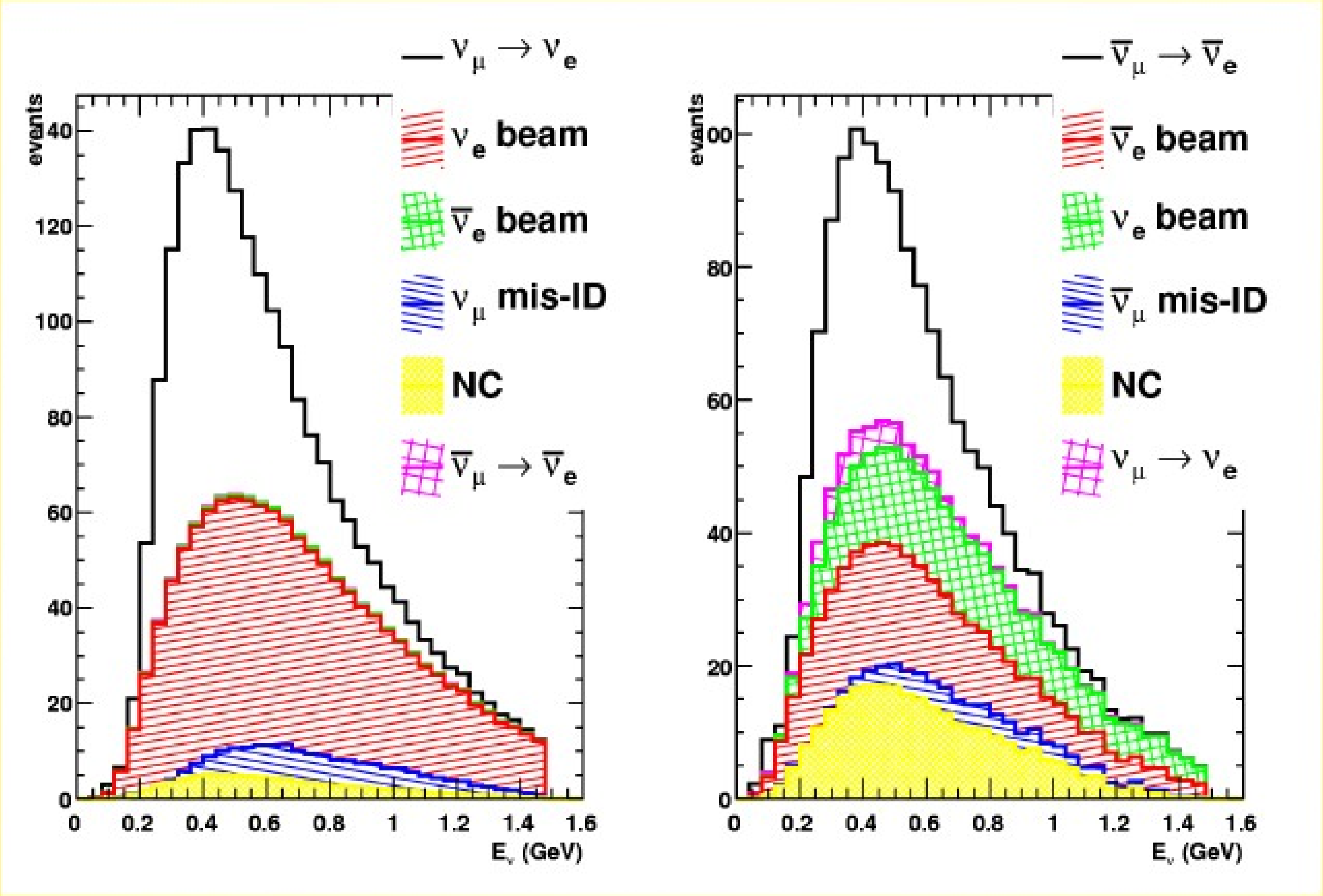


Fluxes in GloBES format are available online here:

http://irfu.cea.fr/en/Phocea/Pisp/index.php?id=54

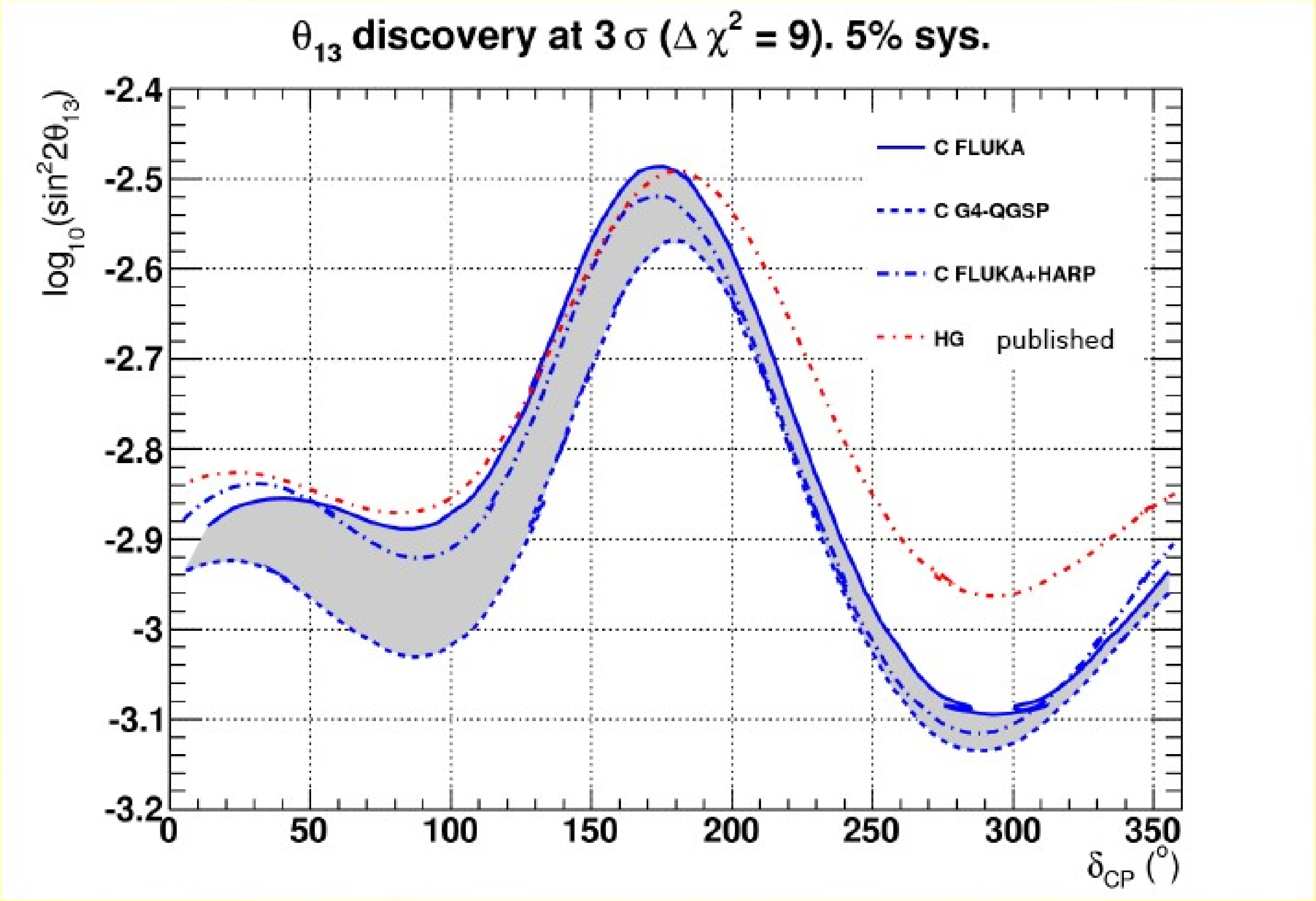
Event rates in MEMPHYS

$\sin^2 2\theta_{13} = 0.01$, $\delta_{CP} = 0$



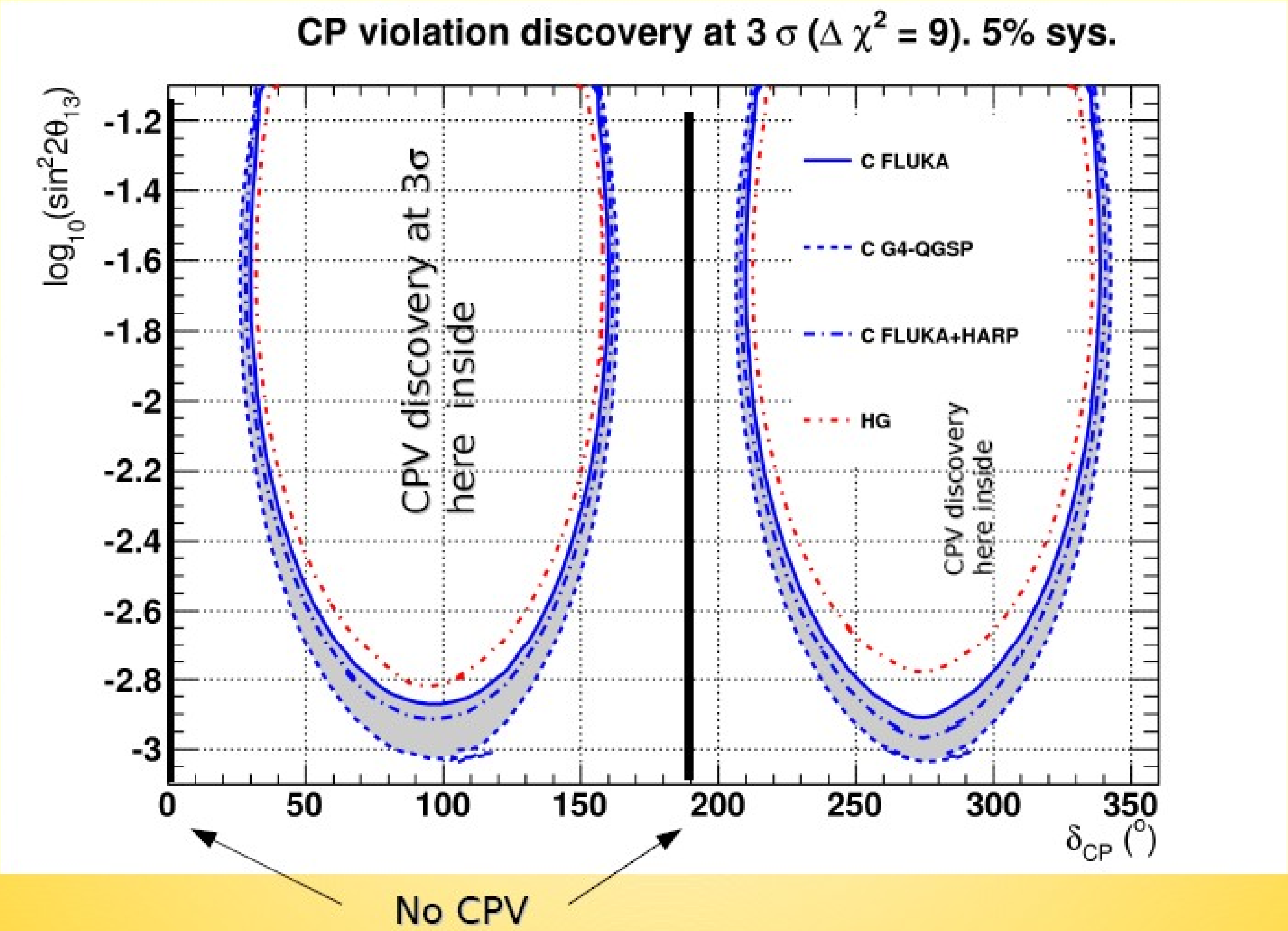
Based on the public MEMPHYS parametrization (AEDL) distributed with GLoBES
Bulk of the background from intrinsic beam electron component

Discovery of $\theta_{13} \neq 0$



Using GEANT4 for p-target interactions or reweighting FLUKA to HARP data yields better limits

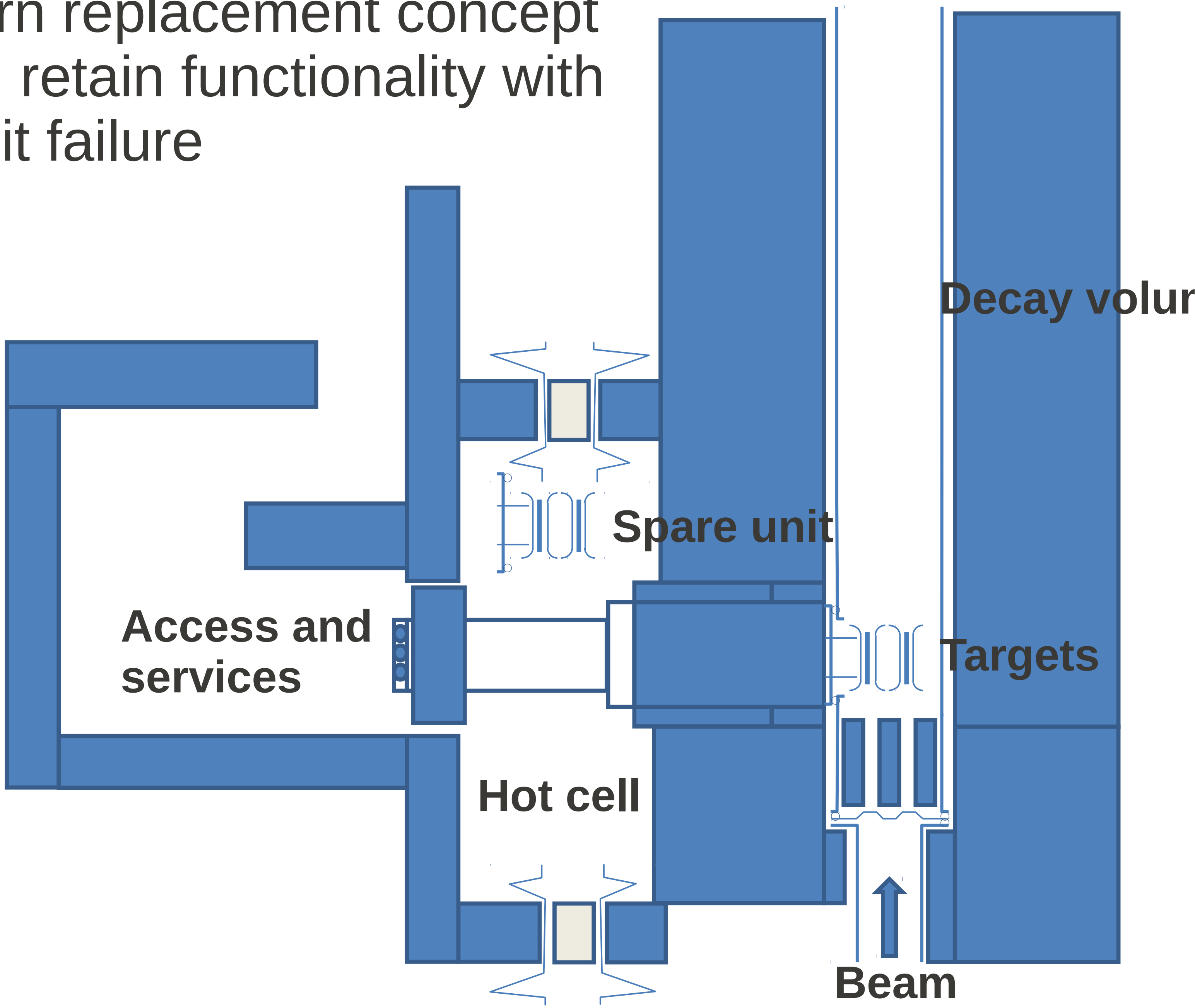
Discovery of CP violation



TARGET STATION CONCEPT

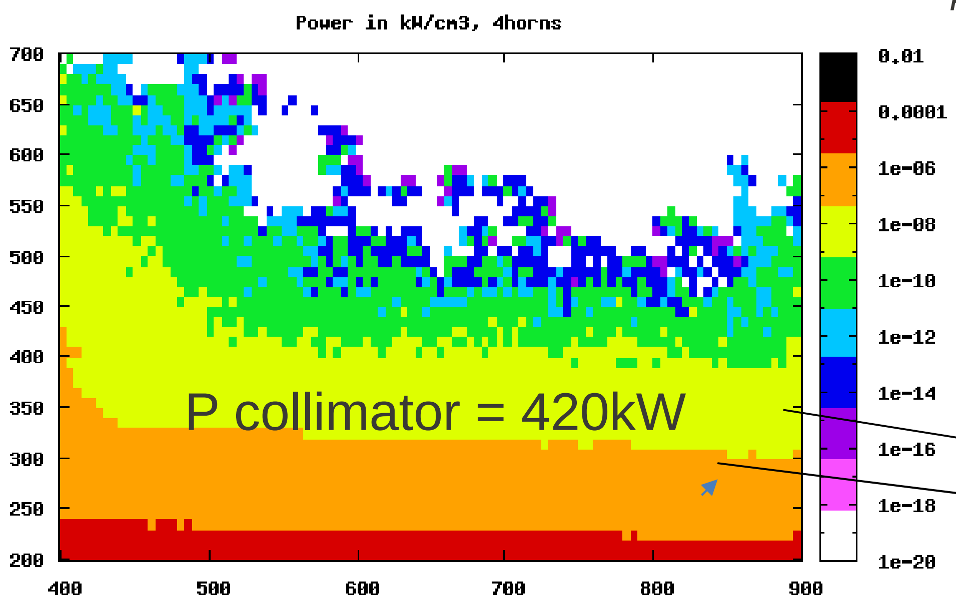
C. Densham

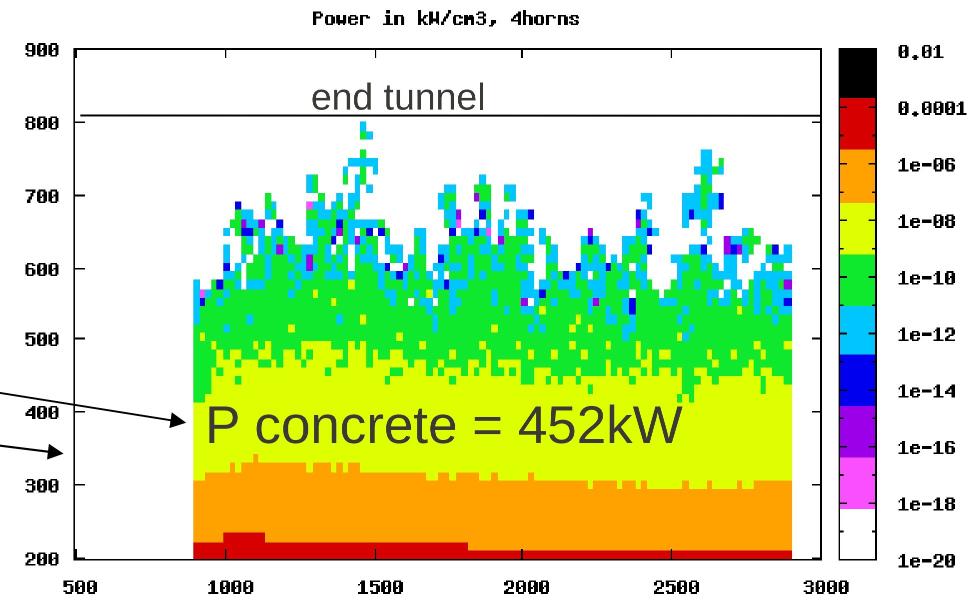
Target and horn replacement concept
Requirement : retain functionality with 1 (out of 4) unit failure
1.3 MW each

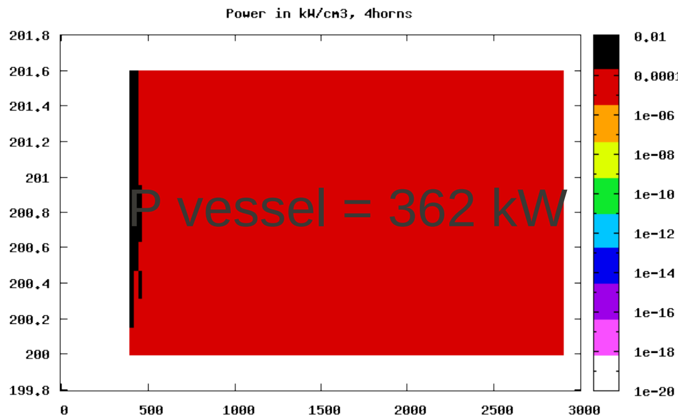


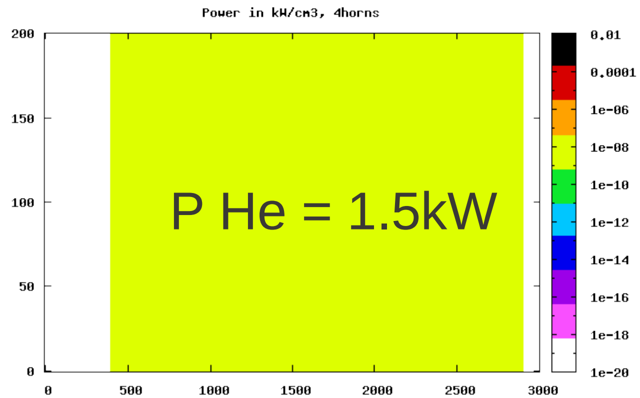
Power in Decay Tunnel Elements

R-Z
Power density distribution in kW/cm³









Conclusions

- We have produced a baseline design for a multi-MW neutrino beam based on SPL(recently completed note 11-01)
- It is composed of four identical systems, with a pebble-bed target and a magnetic horn
- We have produced a detailed simulation of the neutrino intensity and composition, event rates and sensitivity
- We are active on finalizing the design, produce a costing document and elaborate the safety plan

Deliverables

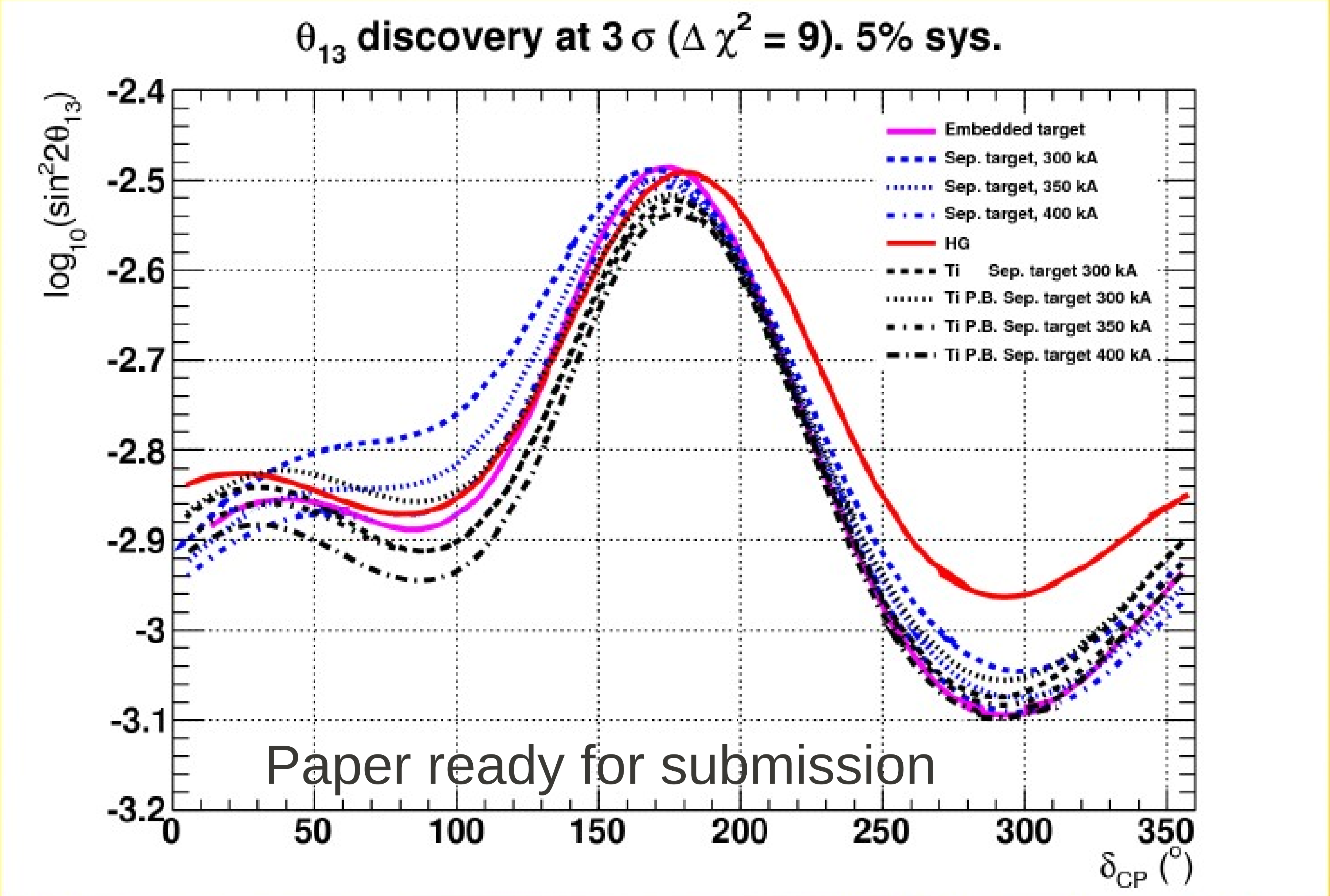
Deliverable	Delivery date (months)	
Requirements for proton driver	6	Completed
Target and Collection design report	30	Completed
Target and Collection integration	36	
Beam characteristics	36	Completed
Final report	48	

Milestones

Milestone	Delivery date (months)	
Proton driver report	12	Completed
Prel. Design of Target and Collection	24	Completed
1st Target and Collection integration drawings	24	Completed
1st Est. of Nu Beam Intensity	24	Completed
Final Target and Collection integration drawings	36	
Design of target station	40	
Report on Nu Beam Intensity	42	

A. Longhin

Θ_{13} discovery potential



Paper ready for submission

Beam window study

- Beryllium with water or helium cooling feasible